Acoustic emission analysis of damage progression in thermal barrier coatings under thermal cyclic conditions

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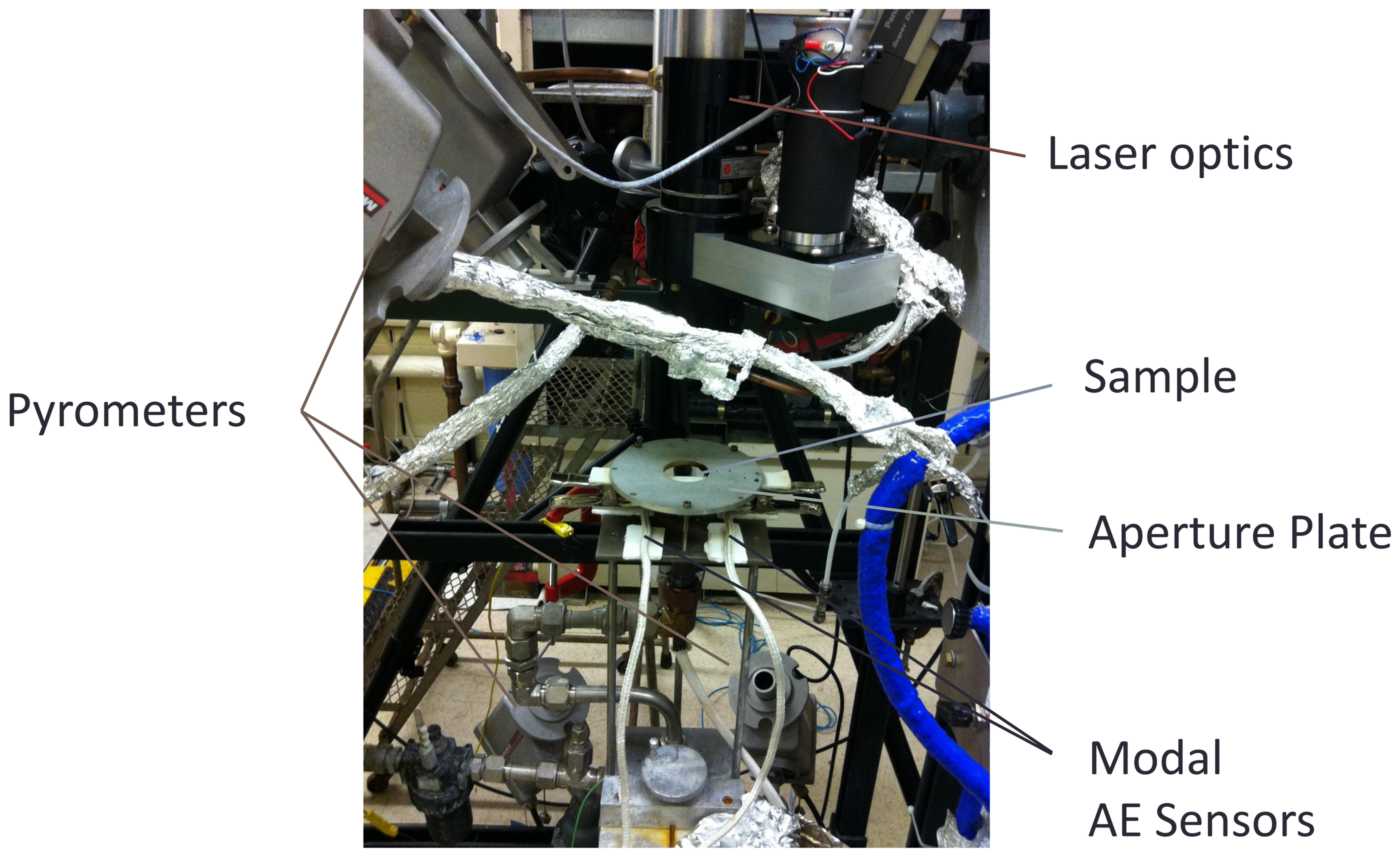
INTRODUCTION

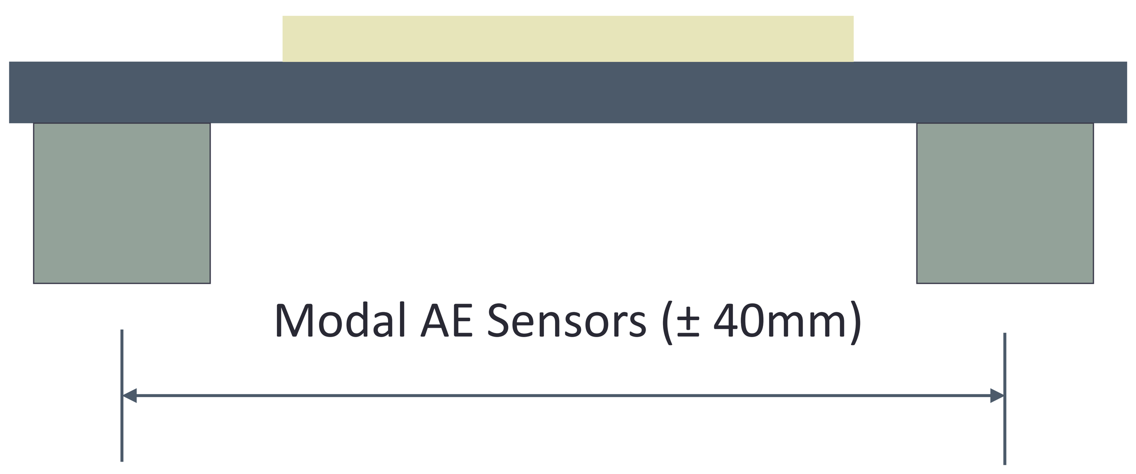
Damage evolution of electron beam-physical vapor deposited (EBVD-PVD) ZrO_2-7 wt.% Y_2O_3 thermal barrier coatings (TBCs) under thermal cyclic conditions was monitored using an acoustic emission (AE) technique. The coatings were heated using a laser heat flux technique that yields a high reproducibility in thermal loading. Along with AE, real-time thermal conductivity measurements were also taken using infrared thermography. Tests were performed on samples with induced stress concentrations, as well as calcium-magnesium-alumino-silicate (CMAS) exposure, for comparison of damage mechanisms and AE response to the baseline (as-produced) coating. Analysis of acoustic waveforms was used to investigate damage development by comparing when events occurred, AE event frequency, energy content and location. The test results have shown that AE accumulation correlates well with thermal conductivity changes and that AE waveform analysis could be a valuable tool for monitoring coating degradation and provide insight on specific damage mechanisms.

EXPERIMENTAL METHOD

Specimens heated using a high heat-flux laser technique. Thermography data was measured in real-time using infrared pyrometers.



Thermal cyclic tests were monitored with high-temperature Modal Acoustic Emission (sensor configuration shown)



MATERIALS

Three configurations of 4" x 0.75" Ni-based metallic substrate with ZrO_2-7 wt.% Y_2O_3 EB-PVD coating:

	Initial Temperature (°C) T_{sur} / T_{back}	# cycles (1 hr)
Sample #1	1477/1095	113
Sample #2	1475/1150	90
Sample #3	1475/1100	109

Sample #1
"As deposited" coating
(used as baseline)

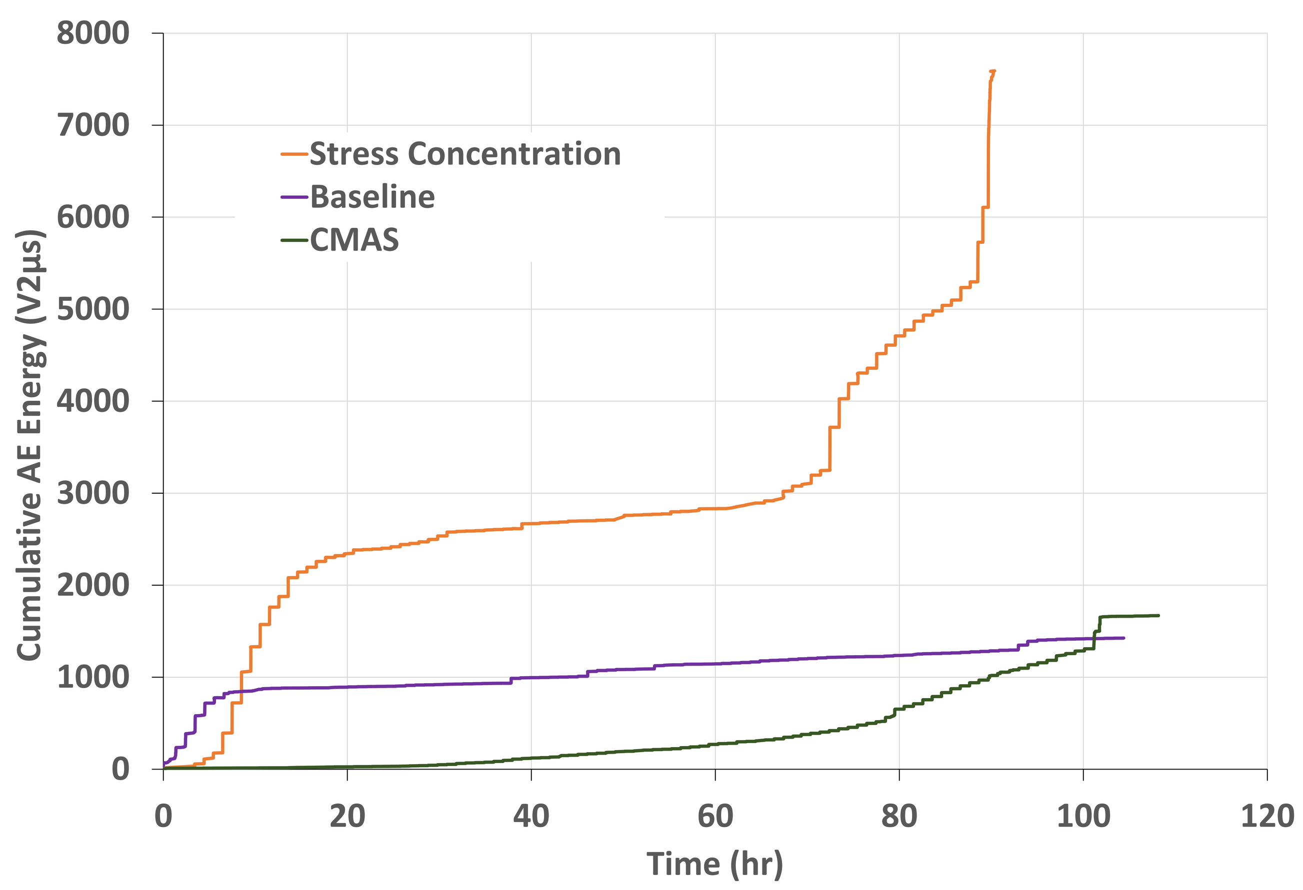
Sample #2
Holes (not fully penetrated) to act as thermal stress concentration (SC)

Sample #3
Coating subjected to pre-test CMAS infiltration

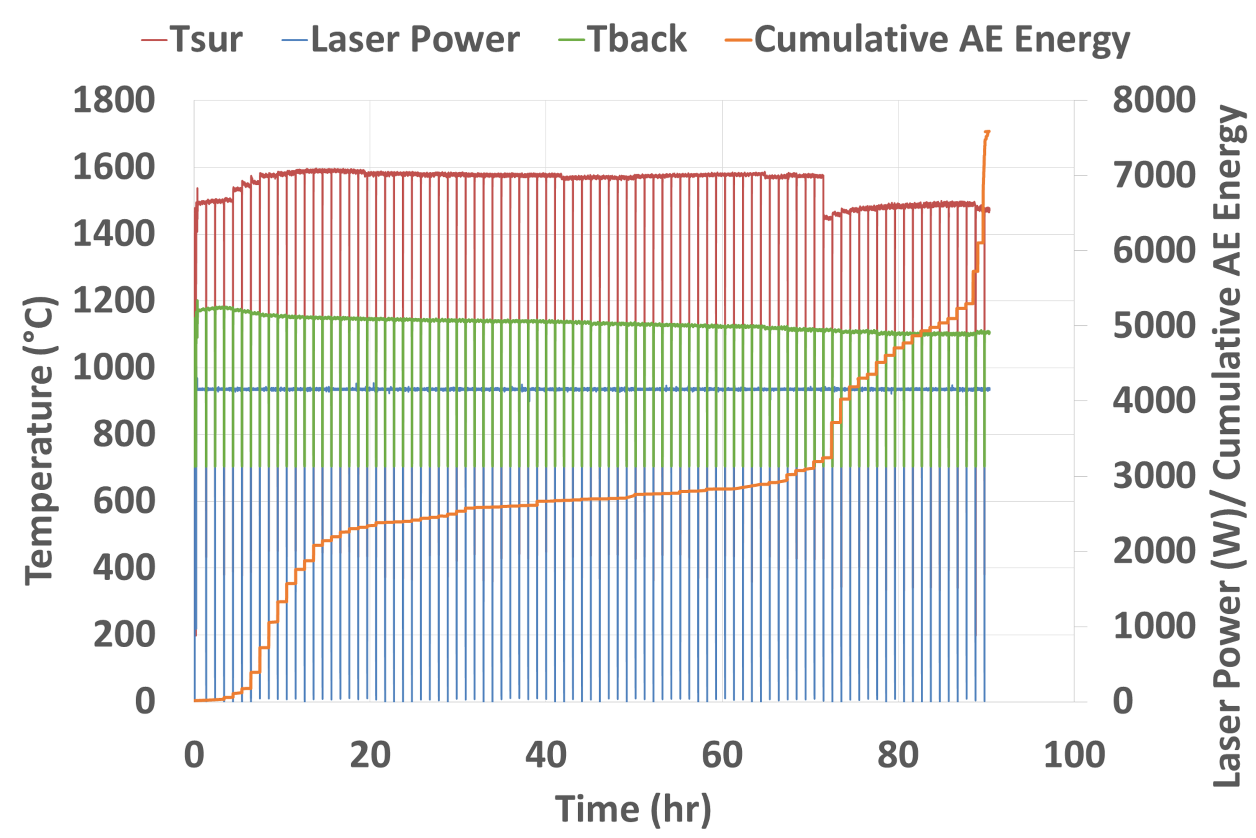
RESULTS

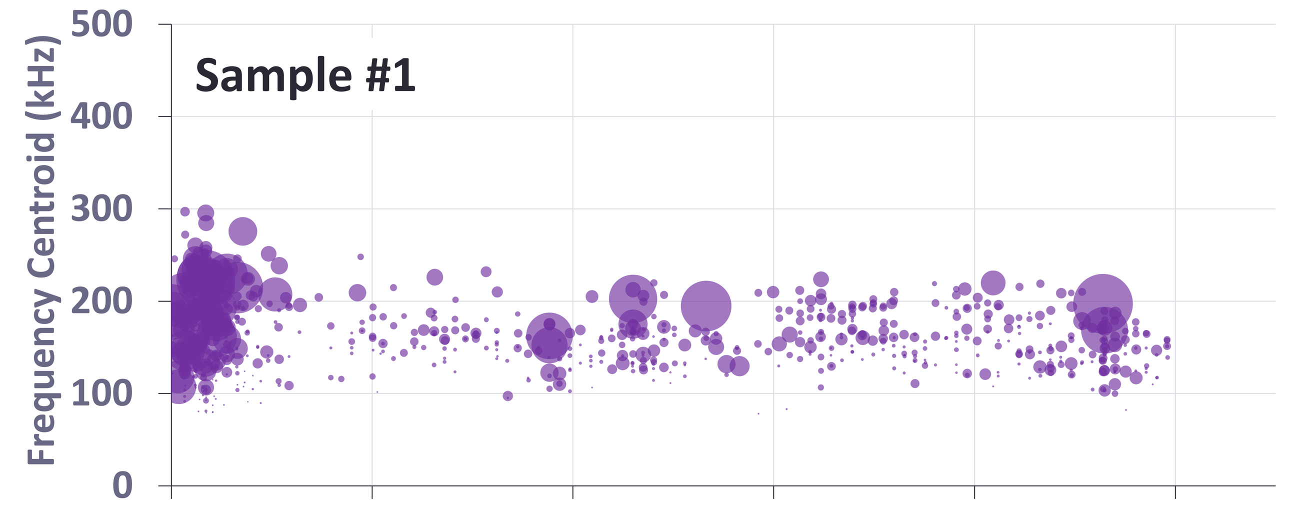
AE waveform analysis is performed to compare damage event characteristics

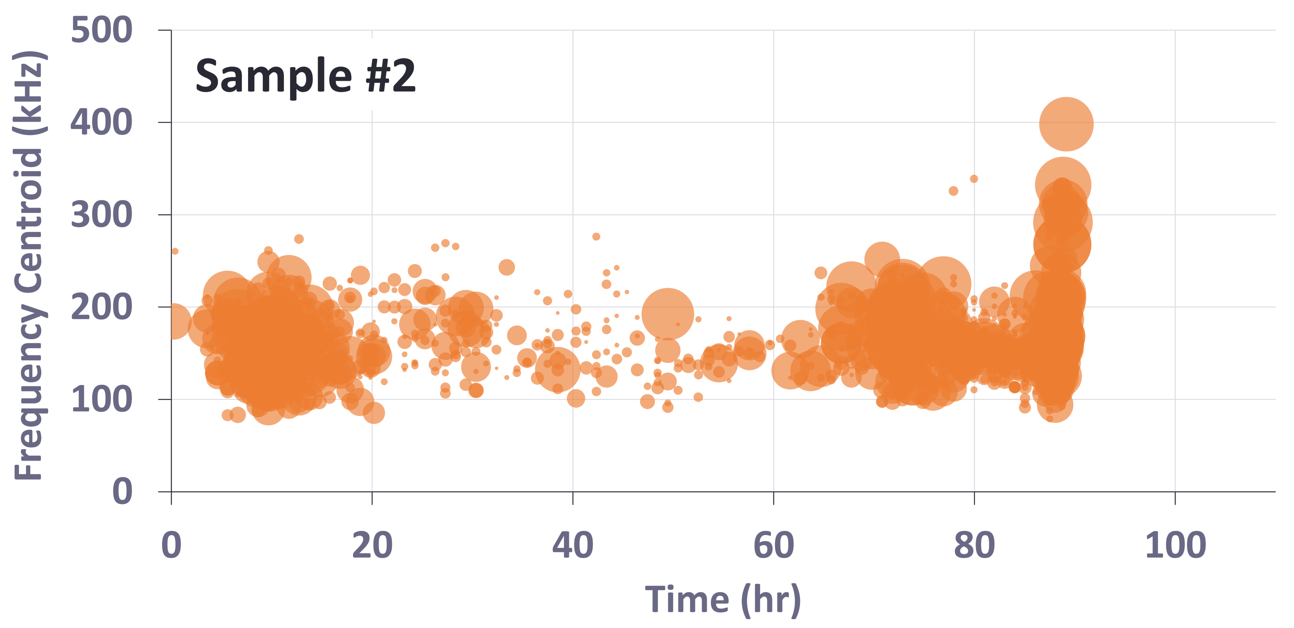
		Total AE Energy ($V^2\mu s$)	# AE Events	Avg. Freq. (kHz)
Sample #1	Baseline	1425	798	162
Sample #2	SC	7564	1565	160
Sample #3	CMAS	1669	896	183

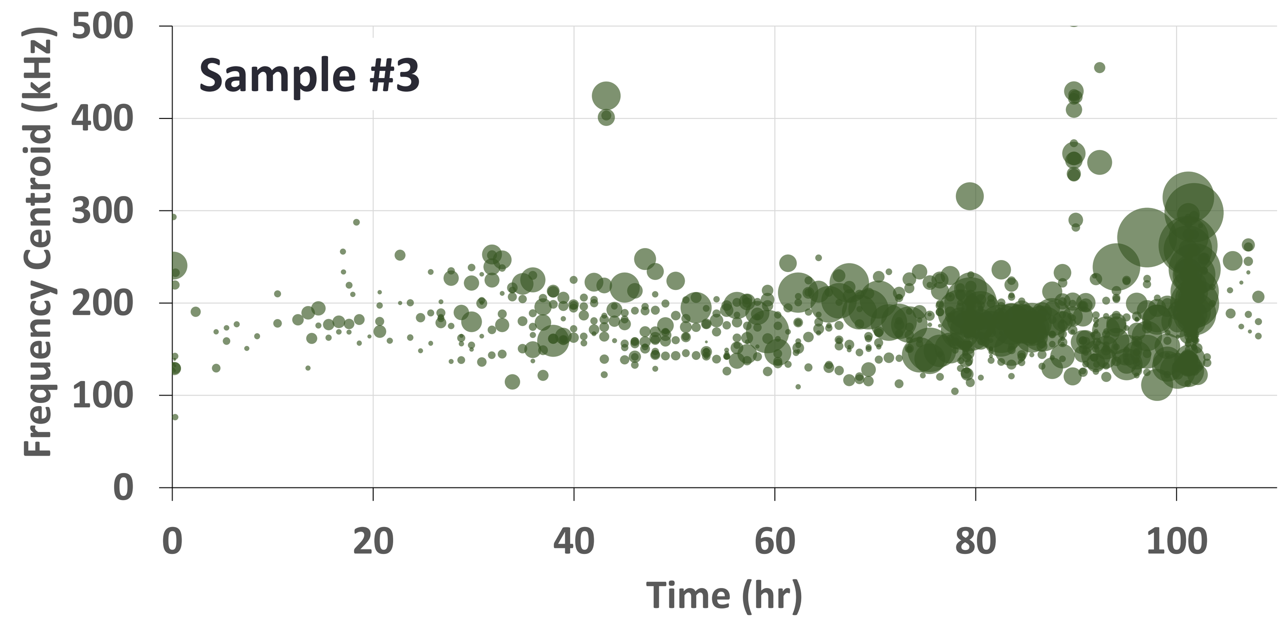


Large scale coating damage seen to correspond to change in thermal conductivity (e.g. spallation near holes)









CONCLUSIONS

While baseline coating saw initial energy accumulation, few high energy events occurred during thermal cyclic test.

For sample containing stress concentrations, the rapid increase in AE Energy correlated well with change in thermal conductivity associated with coating damage.

Started at approx. 40 cycles the CMAS infiltrated sample began accumulating damage at a steady rate, that increased rapidly follow 80 cycles